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A POTENTIAL VORTICITY STREAMER AND ITS ROLE IN THE DEVELOPMENT OF A WEEK-LONG SERIES OF MESOSCALE CONVECTIVE SYSTEMS. PART I: SEVERE WEATHER AND PRECIPITATION

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1. INTRODUCTION

From 27 June to 2 July 1999 a narrow region of positive upper tropospheric potential vorticity (a "PV streamer") formed over the tropical eastern Pacific and persisted over the southwest and south-central United States. During this period, apparently related to the streamer, a succession of mesoscale convective complexes (MCCs) and other severe-weather-producing phenomena developed in the Central and Southern Plains states, primarily Kansas, Oklahoma, Missouri, Texas, and Arkansas. One of these events, a large supercell and MCC that occurred on 27-28 June, produced high winds in Nebraska and Kansas and rainfall and flooding in Kansas and Missouri, inflicting several million dollars of property damage (Caracena *et al.* 2000a).

The coincidence of a PV streamer and subsequent convective weather development have been noted previously. In studies of the European Alps, Appenzeller and Davies (1992) and Appenzeller *et al*. (1996) relate lee cyclogenesis to various upper level PV structures. Massacand *et al*. (1998) suggest that the occurrence of PV streamers may be useful as precursor signals for heavy precipitation in the lee of the Alps.

Because they formed over a data-rich region, the MCCs described here and the convective phenomena associated with them provide an excellent opportunity to investigate the role that PV streamers of this kind played in the development of mesoscale convection on these days and the severe weather that in several cases preceded the MCCs. We describe the location, extent, and type of severe weather that occurred during this period. We also describe the persistent large-scale pattern, particularly the potential vorticity field and its proxy, satellite-observed water vapor. A detailed dynamical study of the first of these serial MCCs on 28 June and its interaction with the streamer is presented in Caracena *et al.* (2000b), also in this volume.

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2. SYNOPTIC PATTERN

The streamer became evident on 27 June, appearing as a narrow region of upper level PV (Fig. 1). The PV-streamer discussed here originated

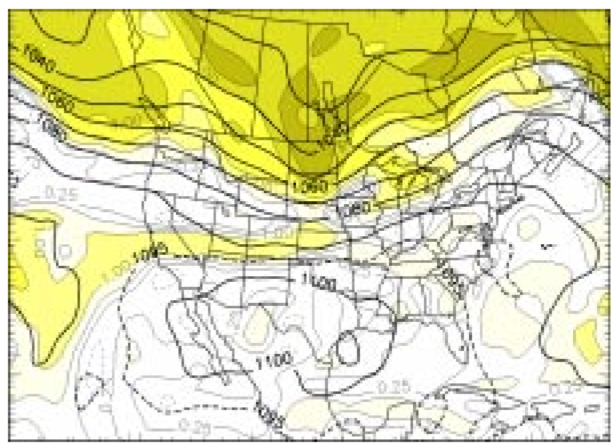

Fig. 1. Potential vorticity (shaded, $K\ kg^{-1}\ s^{-1}\ 10^{-6}$) and geopotential height at 250 hPa based on the 1200 UTC 28 June 1999, 32 km Eta model initial analysis interpolated to an 80-km horizontal grid. Figure adapted from Caracena et al.(2000a).

from a pool of potential vorticity that was extruded and sheared off from a low-latitude trough in a deformation field over the southeastern Pacific at the margins of an upper-level continental ridge. On subsequent days, the streamer followed a track parallel to a series of short-wave troughs in the flow over the northern U.S.

To the extent that the Eta model analysis in Fig. 1 can resolve a feature as relatively narrow as the streamer, it appears to coincide with a pronounced dry slot in water vapor imagery (Compare Fig. 1 with Fig. 2b). The GOES water vapor images in Fig. 2 thus provide a convenient way to illustrate the evolution of the streamer and its large-scale environment. Over the course of several days, the streamer maintained its generally east-west orientation while gradually moving southward from its position extending from central California to Nebraska on 27 June (Fig. 2a) to a position extending from southern California to central Texas by 30 June (Fig. 2d). During the next two days it gradually became less distinct. By 2 July (Fig. 2f) the streamer had been interrupted over Arizona by the emergence of the Southwest monsoon.

Over night between 27 and 28 June, an MCC developed and temporarily diverted or obscured the streamer. This sequence repeated itself on 28 June and 30 June at slightly different latitudes. As described in later sections, the convection from which these MCCs initiated spawned numerous incidents of costly severe weather, and the MCCs themselves produced heavy rainfall. Rodgers *et al.* (1988) have also noted the tendency for MCC development within dry slots like these. The convective systems then

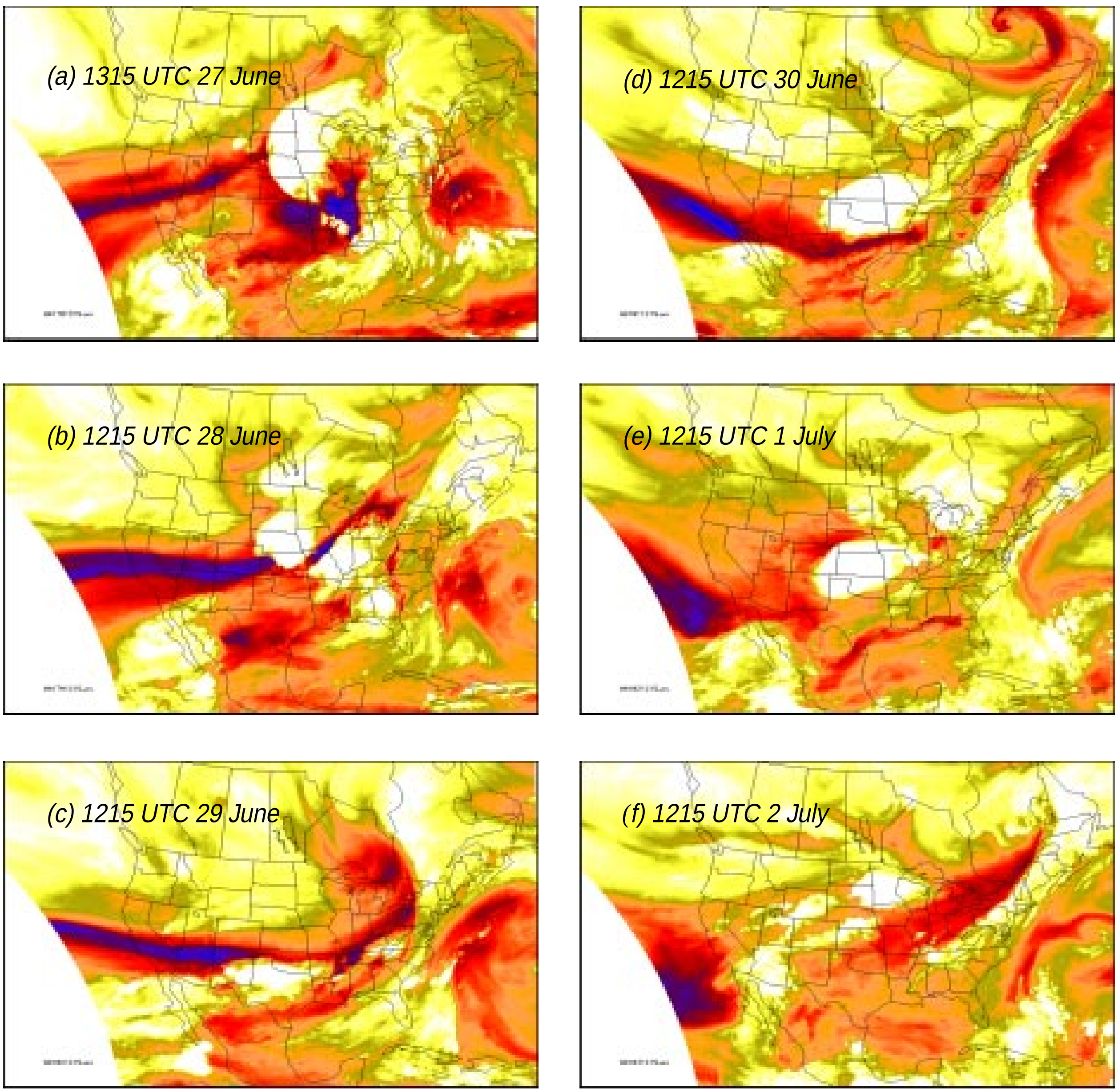

Fig. 2 GOES 8 water vapor images. Light colors indicate clouds and high water vapor content; black indicates low values of integrated water vapor. All dates are 1999.

moved off to the southeast and produced significant rainfall during the subsequent diurnal heating cycle. In several cases, the remnants of mesocale systems appear to have evolved into mesoscale convective vortices (MCVs), which maintained their identity into the next afternoon's convective period and redeveloped into precipitating mesoscale systems (personal communication, Stan Trier).

3. HEAVY PRECIPITATION

Since the synoptic pattern during this period resulted in several episodes of convective development on the Central Plains, it is instructive to examine rainfall observations. Figure 3 shows cumulative rainfall for the period.

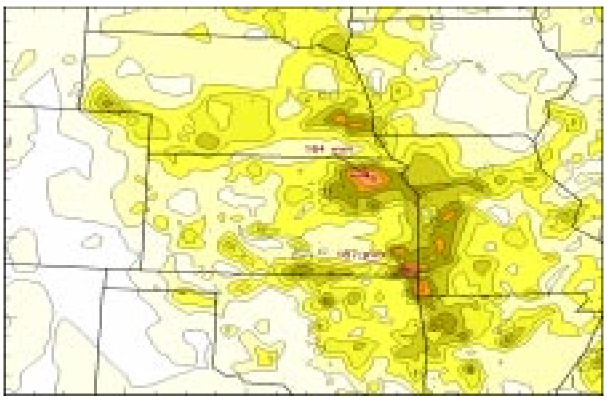

Fig. 3. Rainfall totals (mm) for the period 27 June - 1July 1999 contoured at 20 mm intervals. The analyis is performed using triangulation of a network of surface 24 h gage observations taken at 1200 UTC each day. Data were provided by the National Centers for Environmental Prediction (NCEP).

Several regions of rainfall greater than 100 mm are evident (*eg.*, the darker shaded regions in eastern Nebraska, northeast Kansas, western Missouri, northwest Arkansas, and northeast Oklahoma). This pattern of rainfall seems to match the areas of major mesoscale convective development that show up on Fig. 2, suggesting that most of the rainfall was episodic in nature, primarily falling during the mesoscale convective systems that developed on a few of the days.

The observations of very large daily rainfall amounts plotted on Fig. 4 confirm this suggestion. Each swathe of large rainfall totals approximately outlines the area of mesocale cloudiness on that day. Moreover, these observations also appear to cluster near a dry slot axis on each of these days, and by implication in the path of the PV streamer.

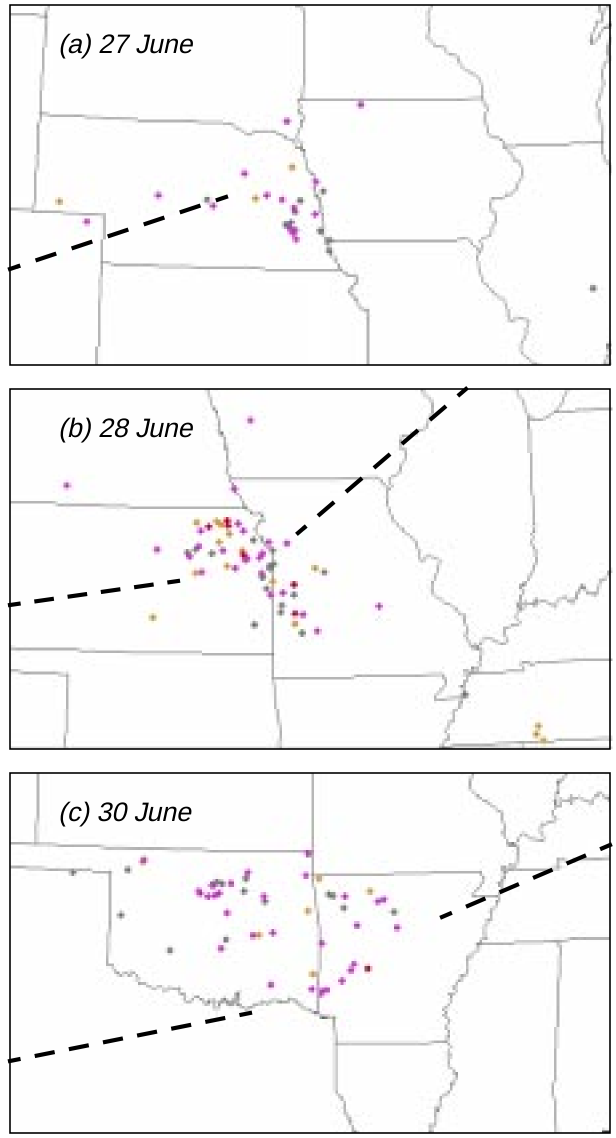

Fig. 4. Locations of observed 24 h (1200-1200 UTC) rainfall totals greater than 50 mm. All dates are 1999. Data were provided by the National Centers for Environmental Prediction (NCEP). Mean locations of dry slot axes for each day are shown as heavy dashed lines.

4. SEVERE WEATHER

Severe weather reports during this 5-day period show a wider distribution than the heavy rainfall observations. The occurrence of tornadoes and hail, in particular, tend to be located in the High Plains in the lee of the Rockies (Fig. 5) . Many of these storms occurred in fast-moving supercells

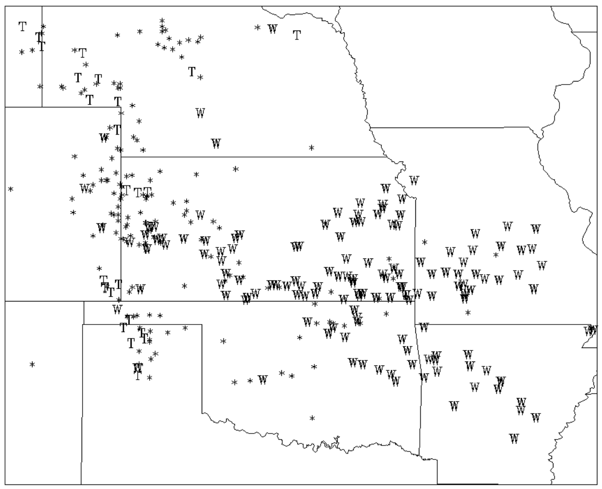

*Fig. 5. Preliminary severe weather reports between 27 June and 1 July 1999. The symbols displayed are T (tornado); * (hail); and W (wind). Data are accessed from the Storm Prediction Center (SPC) Website.*

and squall lines. Upon reaching the dry slot (and PV streamer) axes in eastern Kansas or Oklahoma, these storm systems evolved into MCSs that primarily produced strong wind gusts and heavy rain, often along mature fast-moving squall lines (particularly on June 27 and 28; see Caracena *et al.* 2000a). The relationship of the wind gusts to mesoscale systems is illustrated on Fig. 6, where the high wind reports tend to cluster at the same latitudes and times at which MCCs or MCSs developed.

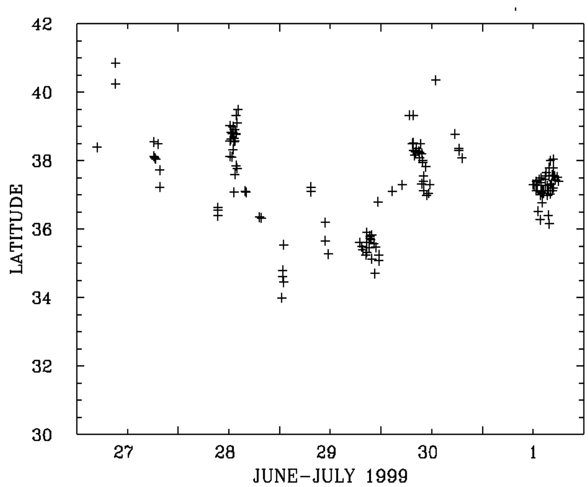

Fig. 6. Time series of preliminary severe wind reports accessed from the Storm Prediction Center (SPC) Website.

5. CONCLUSIONS

The satellite and severe weather observations presented here are intended to establish and describe the relationship between major mesoscale development and a long-lived upper level potential vorticity structure (PV streamer). Further research on the dynamical relationships between the streamer and low level potential vorticity sources will be necessary to demonstrate the usefulness of these features to the understanding and forecasting of MCS development.

6. ACKNOWLEDGMENTS

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